

ATV TOWED MAGNETOMETER SYSTEM FOR ORDNANCE DETECTION

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Abstract

Currently available GPS technologies have enabled surveys for UXO detection with data-positioning and navigation in real-time. In August 1998, Geophysical Technology Limited (GTL) used a real-time Differential Global Positioning System (DGPS) with a towed trailer array of magnetic sensors to perform UXO detection over approximately 200 acres of the Helena Valley in Montana, USA.

The one-person operated trailer system did not require a grid set-up prior to the commencement of the surveys. The survey computer guided the operator along the survey lanes with an absolute cross-track accuracy of 0.75 metres (vegetation and terrain permitting). An expandable array of magnetic sensors with adjustable height and separation allowed the operators to optimise the system for this application. Eight sensors, 0.5 metres apart were used in the survey.

In Montana, accurate, real-time DGPS positioning and navigation resulted in the good coverage of the survey area using the trailer system. The standard deviations of positions of magnetic data were recorded and provided essential data quality control. A standard ATV was used for the entire Montana survey.

The GTL trailer system enables practical, fast collection of high-resolution, accurately positioned magnetic data, as required for UXO detection. The GTL trailer system opens new possibilities of covering large areas efficiently and it is an important milestone in achieving effective large-scale remediation with performance that is quantifiable.

Introduction

UXO detection can be effective without million dollar budgets. Such high budgets are no substitute for experienced geophysicists. These experienced operators can use detection technology up to its limit. Knowledge and measurement of these limits quantifies the performance of the UXO detection survey.

A recent UXO detection survey performed by GTL in a residential area with a low-cost vehicle magnetometer system had its performance measured independently. The high measured effectiveness of the detection survey in that scenario gives the end-users an indication of the value for money spent on the hazard reduction operation.

The survey took place in Helena, Montana in 1998 for Linda Daehn of Tetra Tech EMI and Dr. Clif Youmans representing the Montana National Guard.

The Towed Array Magnetometer System

1.1 Low Cost Towed Array Magnetometer Systems

The main feature of the system is the low cost of the trailer and the use of any standard 4 wheel bike to tow the array. This means that the system can be easily duplicated and multiple systems can be run on large or concurrent projects. The efficiency of the system comes from the speed of traverse, the 4 metre swath width, and the complete coverage achieved with DGPS navigation. The TM-4 magnetometer at the center of the system is the same instrument used in the hand-carried application for performing in-fill of areas inaccessible to the trailer system.

1.2 UXO Detection by the TM-4 Magnetometer

Ferrous unexploded ordnance and ammunition related items may be detected by measurement of the magnetic field associated with metallic iron. The TM-4 magnetometer system has been developed for this specific application and has been recognised internationally¹ as a leading technology in this field. The magnetic method has advantages of relatively low data acquisition cost and the ability to detect ferrous items to a greater depth than can be achieved using other methods. Its disadvantages are that it can detect ferrous UXO only and it can be subject to interference from magnetic minerals in the soil.

¹ After extensive trials by the US Army Environmental Center between 1994 and 1996.



Figure 1. The TM-4 DGPS navigated and positioned, eight sensor towed magnetometer array. This figure also shows the ideal country encountered in Helena.

Field Procedures Adopted

The area to be surveyed was divided into blocks defined by barriers to the vehicle such as fence lines. The location of the corners of each block was then determined with the DGPS. These locations were programmed into the TM-4 navigation software.

The navigation software then calculated the start and end coordinates of a pattern of parallel survey lines separated by 3 metres and oriented parallel the longest axis of the block. While the effective swath width of the sensor array was 4. metres, the choice of 3 metre line separation provided a data overlap that allowed for a permissible cross-track navigation tolerance of up to ± 0.85 metre. Each survey line was automatically assigned a line number. For Quality Assurance tracking at the commencement of a survey session, the operator entered into the navigation package the number of the first line to be surveyed. A navigation bar on the instrument console was then used to steer to the nearest end of the requested line. As the sensor array reached within 2 metres of the start of the line, data recording was automatically commenced. The steering bar then guided the operator down the required line by graphically displaying the deviation off the required track in units of 0.1 metre. On crossing the end of the survey line, the navigation system then automatically stopped recording data, incremented to the next survey line number and guided the operator to its start point as before.

The accuracy of the DGPS system used (typically better than 0.2 m) enabled the operator to navigate along a line with generally less than 0.5 m cross-track error.

Data was processed daily to monitor as an in field QA feature. In the event that the excessive cross-track error resulted in a hole in the data, then the relevant line was resurveyed.

Prior to the commencement of the survey, a synchronised base-station magnetometer was set recording at five second intervals at a location away from interference from magnetic sources. The differential GPS system used also required the establishment of a reference base-station that was linked to the mobile unit by radio.

Interpretation of the Data

GTL's proprietary MAGSYS program was used for detailed anomaly interpretation and the printing of colour images. The colour images, each representing a 50 by 50 metre sub-grid area were printed with numbered interpretations overlain.

Data interpretation was performed on each of the sub-grid blocks. The colour image of each block was manually scanned to identify target anomalies. All anomalies exceeding 7 nT in amplitude were interpreted. MAGSYS has the facility to view target anomalies in both colour image and isometric views. Both views may be zoomed to size and the isometric images may readily be rotated as an aid to visualisation and detection of geologically sourced anomalies.

Magnetic targets identified in this manner were then modelled using a semi-automatic computer-aided procedure within MAGSYS. This procedure was very fast but it relied upon fitting a single profile to a forward model of a magnetic dipole. The modelled profile was automatically selected to include both the anomaly maximum and minimum. A selection of key parameters (position, depth, approximate mass and magnetic inclination) was used to adjust the shape of the model for best fit. The key parameters of position, depth and approximate mass were then reported. The confidence that the interpreted items were UXO were scaled as high, medium, and low according to their least squares fit value. Those that were very low were not reported.

Positional Accuracy of Interpreted Targets

Both the data acquisition and data processing aspects of the detection task determine the positional accuracy of interpreted targets. The final positional error could be as much as the sum of each contributing error.

The radial positional tolerance in magnetic grid survey data acquisition was less than ± 250 mm. The magnetic modelling of the grided data set is expected to result in a positional error not exceeding half the line spacing (250 mm) perpendicular and parallel to the survey direction.

Summing the positional errors from both sources above, then the worst case radial positional error in targets interpreted from the magnetic grid data should not exceed 700 mm.

Independent Assessment of Detection and Positional Accuracy

Table 1. Summary of Detection Result Of Emplaced Items

Item	Number	Number	%age	Confidence			Typed
Type	Emplaced	Detected	Detected	High	Medium	Low	Correctly
76-mm	24	23	96%	19	0	4	23
81-mm	5	5	100%	4	0	1	5
60-mm	5	0	0%	0	0	0	na
all	34	28	82%	23	0	5	28
76&81	29	28	97%	23	0	5	28

Table 2. Summary of Positional Accuracy of Detected Emplaced Items

Error	Average
Type	(m)
Depth Error	.11
Radial Error	.40

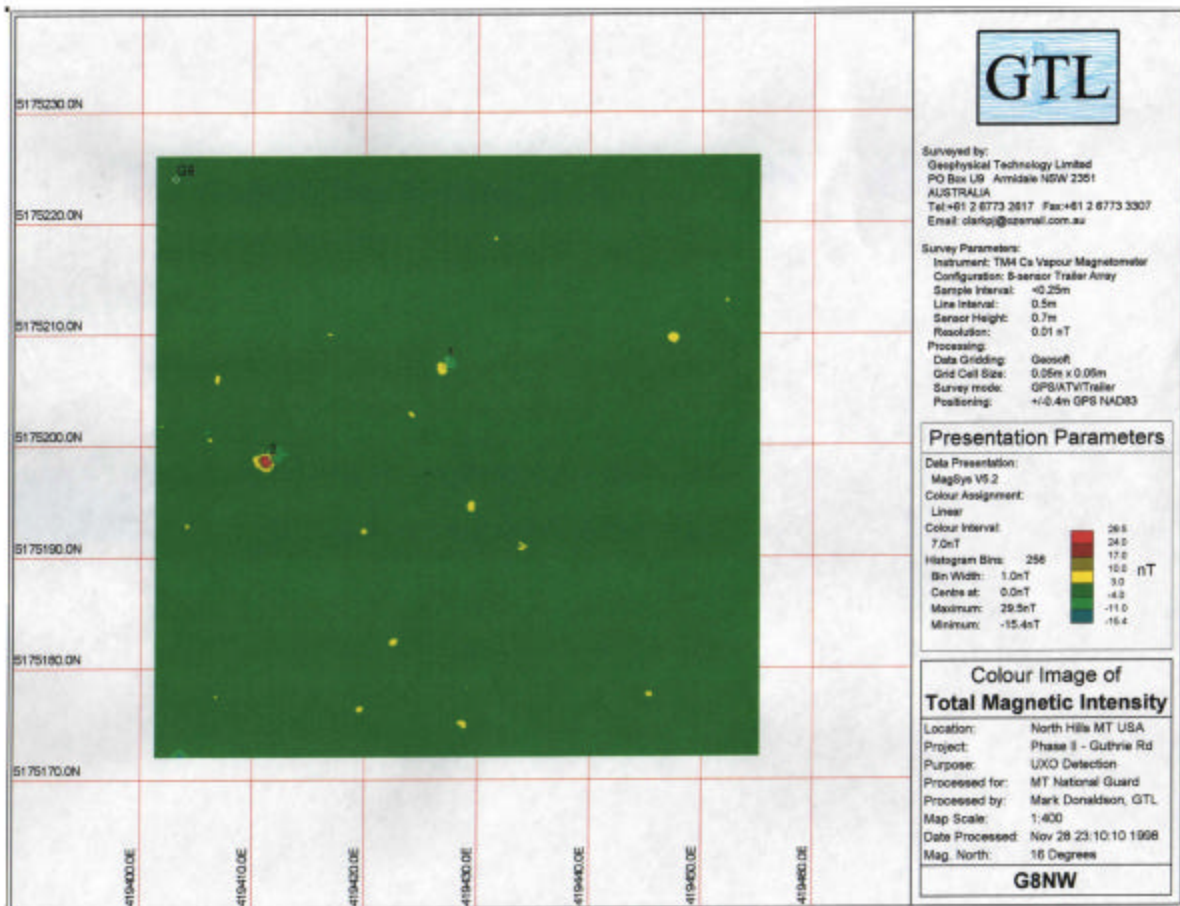


Figure 2. Sample Colour image of data collected with 8 sensor vehicle towed system in Helena. Interpretation Number 2 is an emplaced 76mm projectile that was clearly detected.

Table 1 shows that GTL's system has successfully detected over 95% of the emplaced 76 mm and 81 mm mortar to depths expected in this scenario. Table 2 shows that this was done with high degree of horizontal (average of 0.40 metres) and vertical (average 0.11 metres) accuracy. Figure 1. shows a sample colour image used for detecting anomalies. The emplaced item's anomaly can be clearly seen.

Conclusion

The simple, inexpensive DGPS navigated, 8 sensor magnetometer ATV towed system can effectively detect UXO to a measurable effectiveness.

References:

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Peter Clark has received his M.Sc. (New England Australia). He did his post-graduate Research in potential field gradient measurement and analysis. He now has 15 years geophysical experience, including 12 years in environmental UXO geophysics with Geophysical Technology Limited (GTL). Mr. Clark specialises in DGPS applications and vehicle mounted systems. He is also working on 3-D computer modelling, spectral analysis and parallel processing for the geophysical detection of hazardous materials. He is a member of AIG, ASEG and SEG.